2012-08-01

Modeling and Simulating Environmental Effects

Guest, Peter S.

Monterey, California: Naval Postgraduate School.

Modeling and Simulating Environmental Effects

Peter S. Guest[1], Speaker
Tom Murphree[1], Speaker
Paul A. Frederickson[1]
Arlene A. Guest[2]

Environmental Effects Group
[1]*Department of Meteorology*
[2]*Department of Oceanography*
Naval Postgraduate School
Monterey, California

MOVES Research and Education Systems Seminar
August 1, 2012

Our Goal Today:

Encourage You to Think About How The Physical Environment May Affect the Scenario You Are Modeling and Simulating

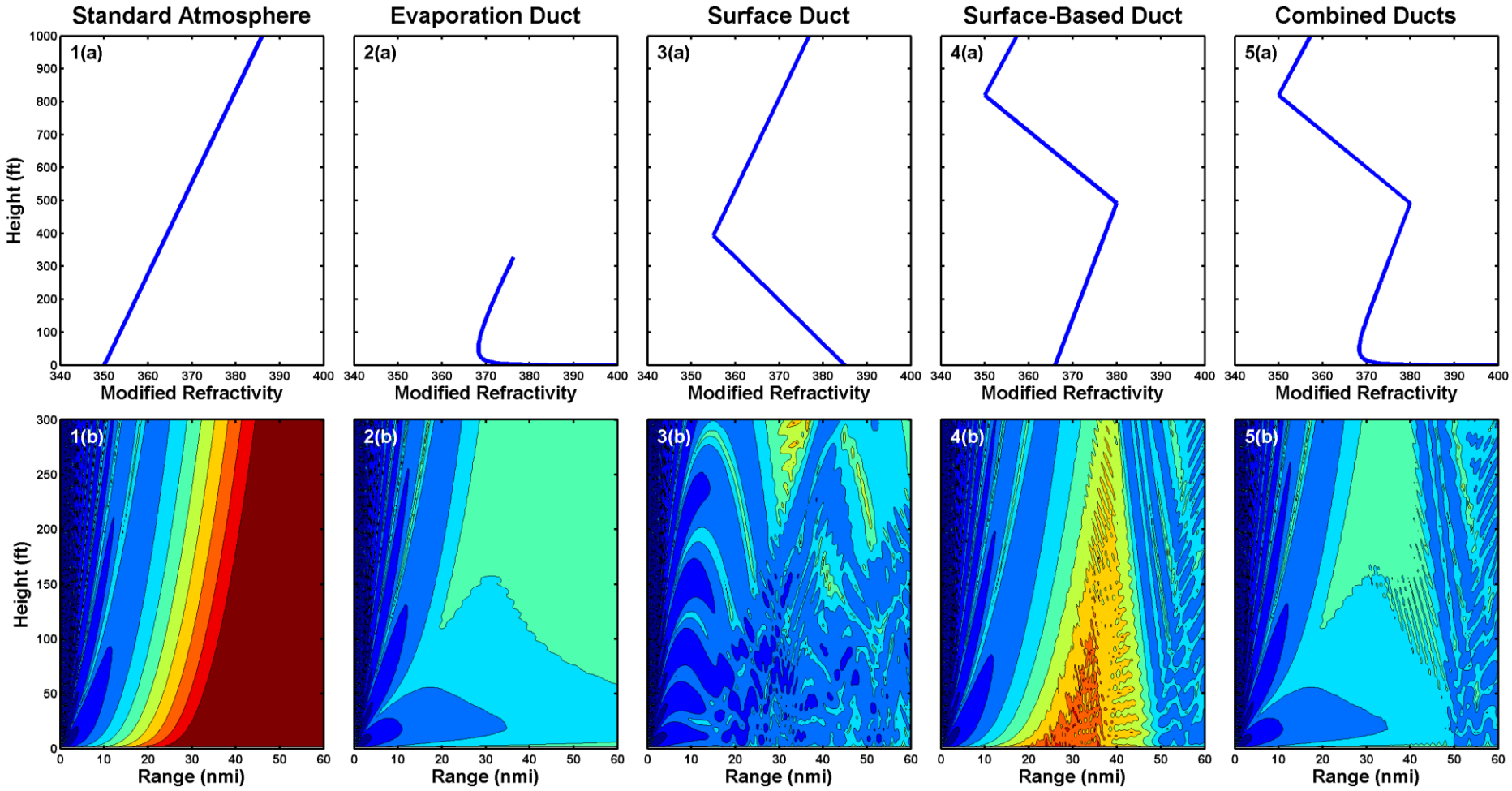
- **Radio Waves**
  - Radar, Communications, Jamming, Surveillance
- **Optical Effects**
  - Visibility, Mirages, Turbulence,
  - Sun Glare, Dust, Pollution
- **Weather**
  - Heat, Cold, Snow, Rain = Mud
  - Humidity, Clouds, Icing, Storms
- **Ocean**
  - Sea State
  - Acoustics
  - Currents

Outline

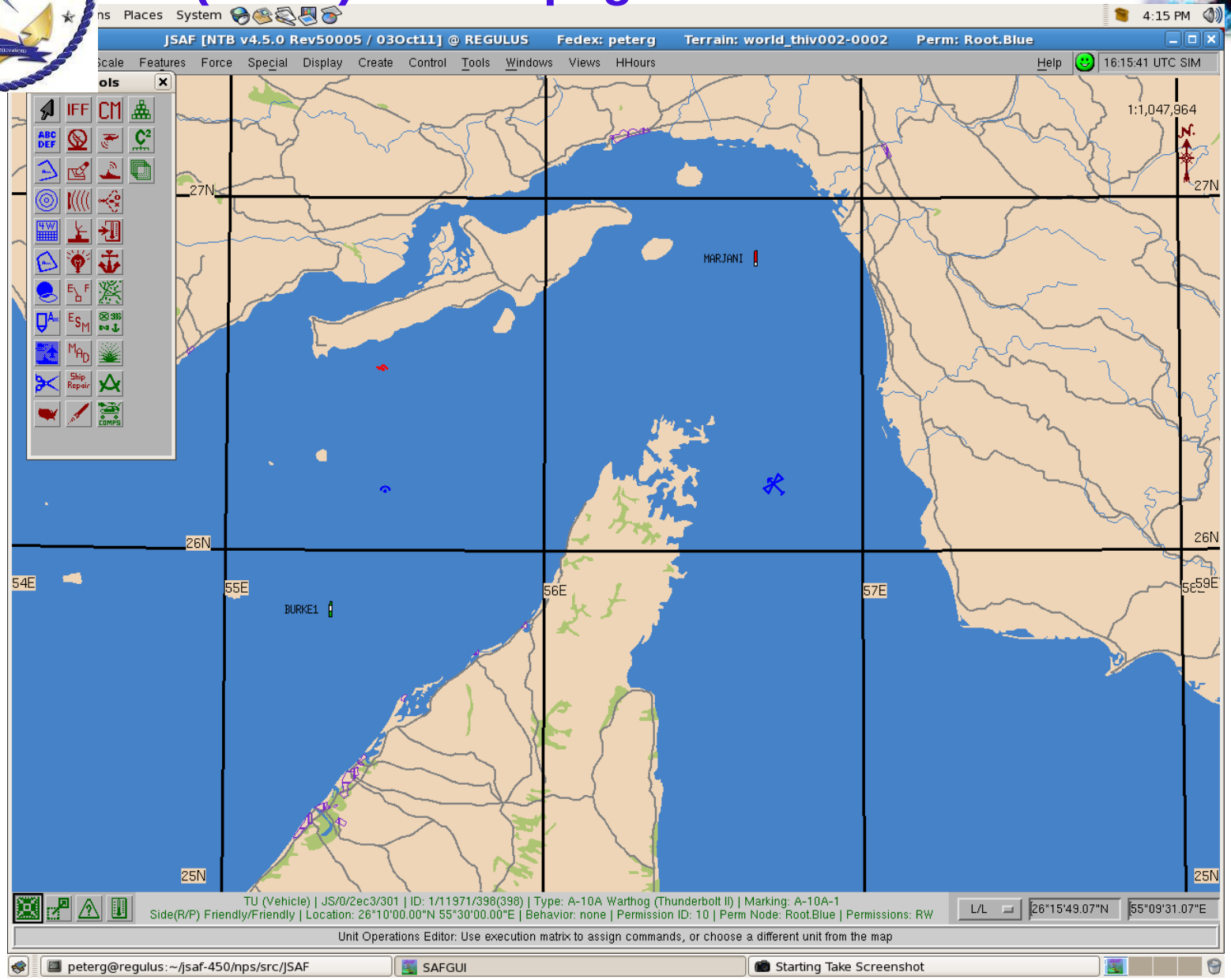
- **Electromagnetic Propagation (EM) Modeling**
  - **Collaboration with Naval Warfare Development Center (NWDC) to improve EM system modeling in Fleet Synthetic Training**
  - **Improving Fleet EM tactical decision aids (TDAs) to provide operational and planning guidance for warfighters**
- **Advanced Climate Analysis and Forecasting**
  - **Goal: Improve the representation of the effects of Earth's climate system on DoD, national intelligence, humanitarian assistance, and other operations.**

Impact of Different Atmospheric Conditions on Electromagnetic (EM) Propagation

- Different atmospheric conditions have distinctly different impacts on EM propagation. Therefore: **<u>We have to get the environment right for accurate and realistic EM system performance modeling and simulation</u>!**

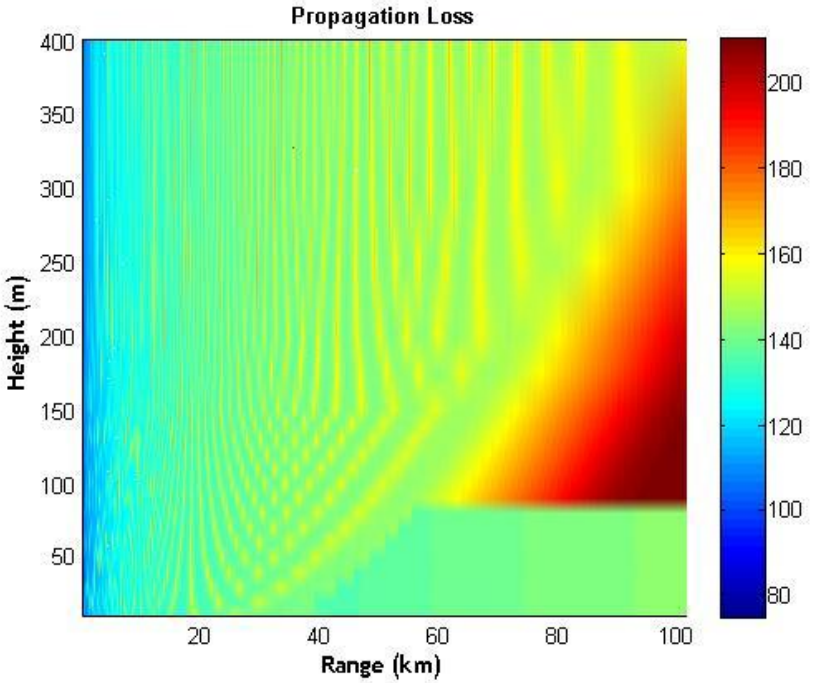


NWDC Joint Semi-Automated Forces (JSAF) EM Propagation Prediction

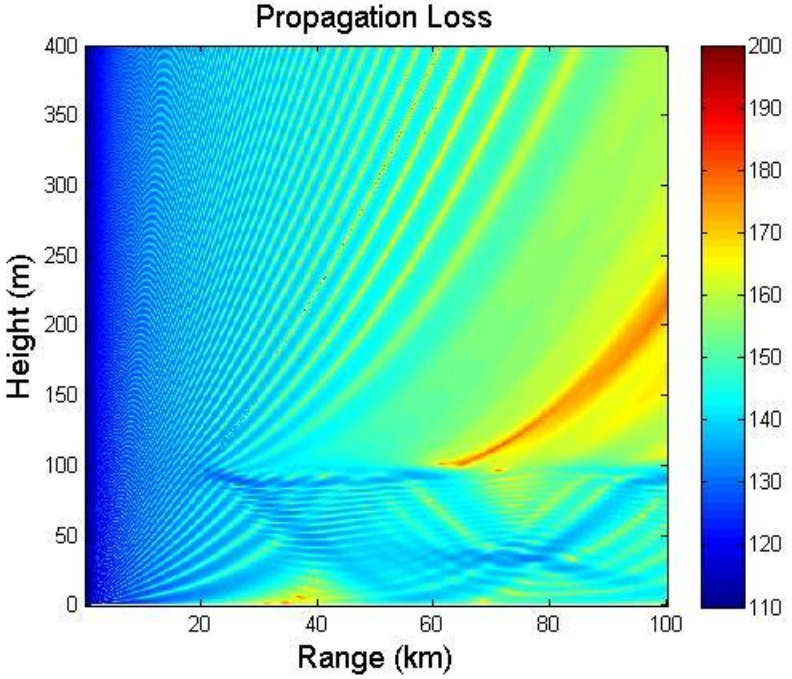


EM Propagation Predictions

JSAF (FFACTR)



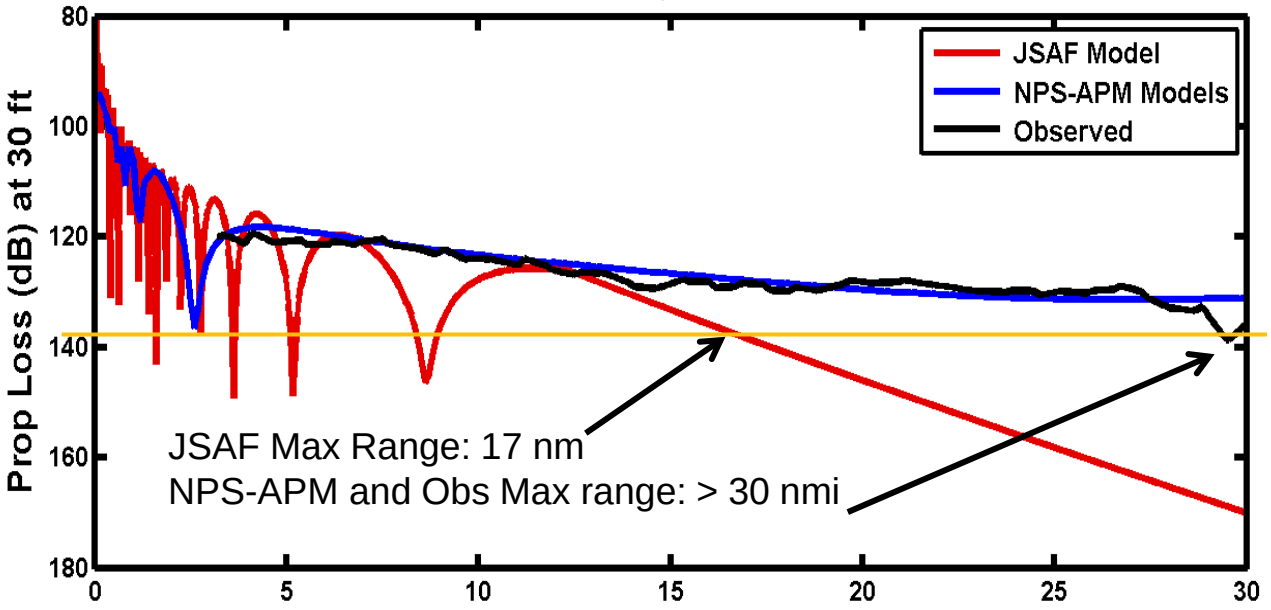
APM



Environment: "Weak" Surface-Based Duct below 100m
Antenna Height: 34m
Frequency: 800 MHz

Radar Detection

A validation of the current JSAF propagation model and atmospheric representation, and the proposed APM propagation and NPS evaporation duct models, demonstrates that the proposed APM/NPS models have vastly superior performance when compared to actual EM propagation observations.



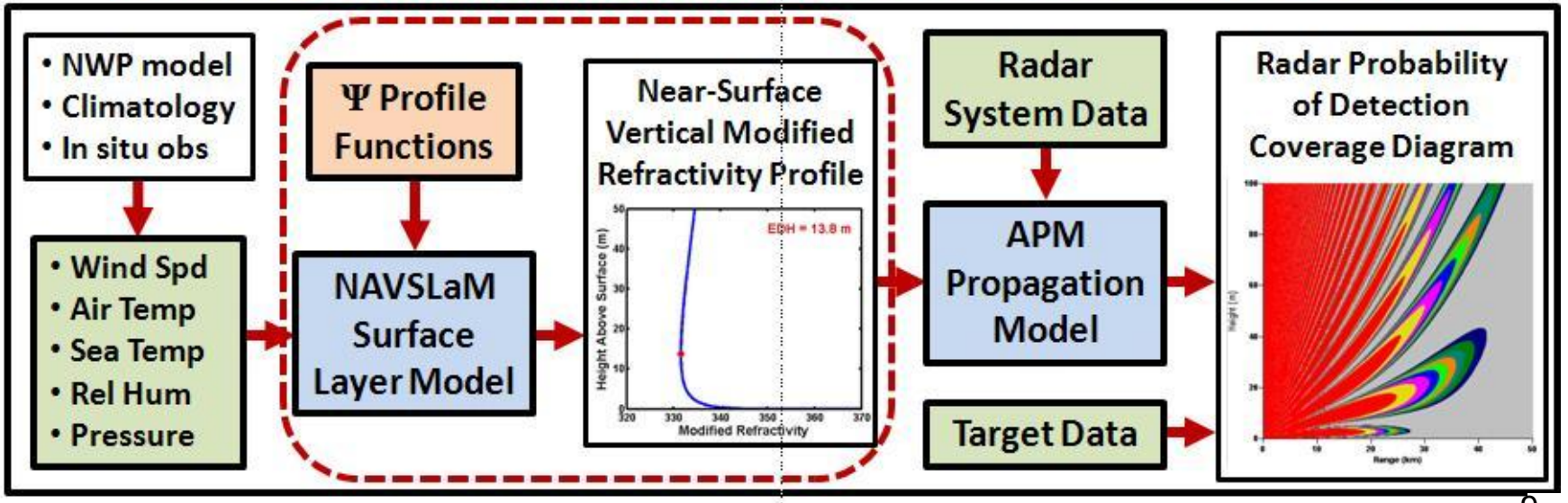
Sample Radar Detection Threshold

Data are from the Wallops Island, VA, 2000 propagation experiment.

Navy Atmospheric Vertical Surface Layer Model (NAVSLaM)

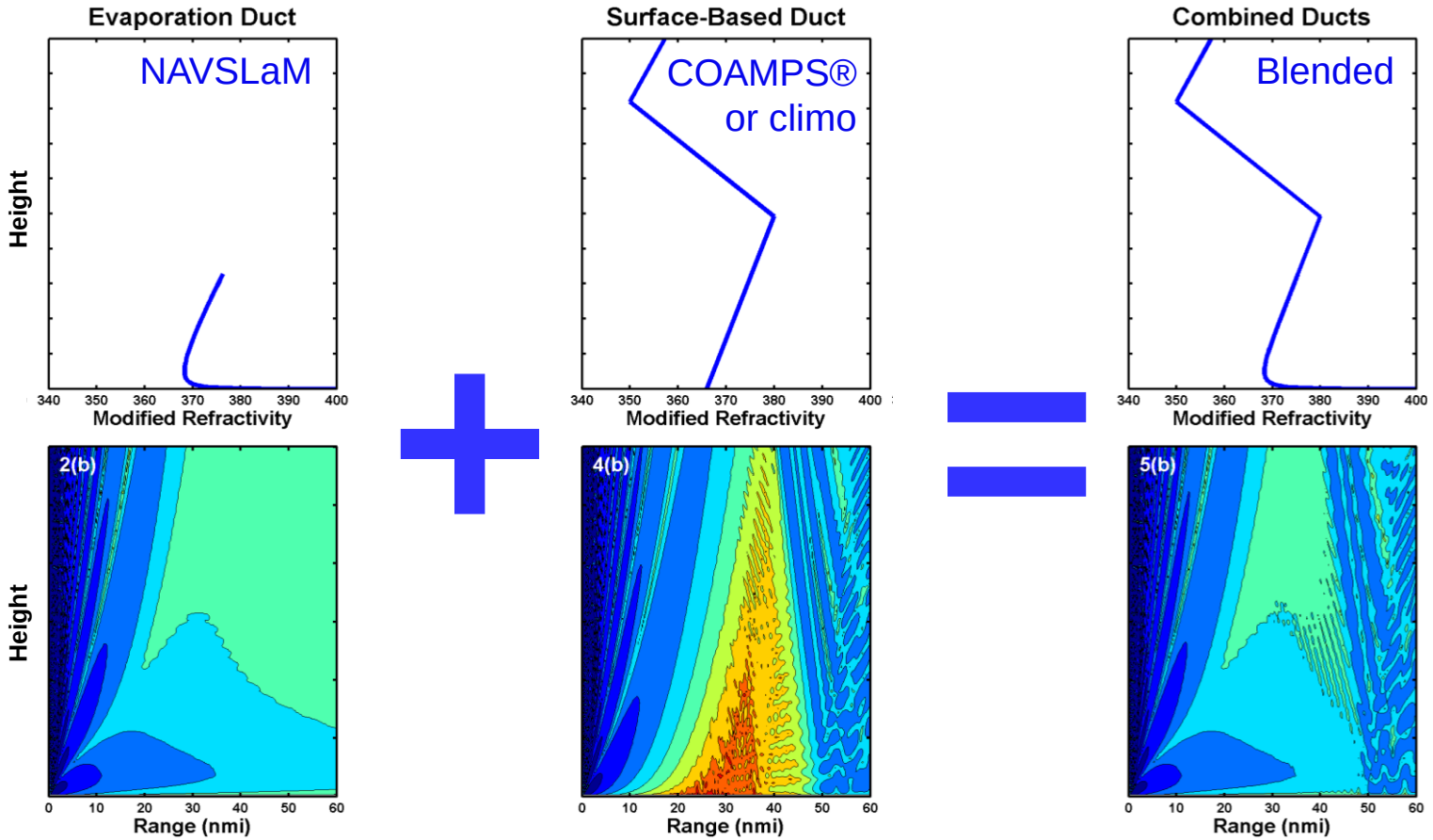
- NAVSLaM is the U.S. Navy standard surface-layer refractivity (i.e. 'evaporation duct') model, residing within the Oceanographic and Atmospheric Master Library (OAML) since 2010.
- Developed by the Department of Meteorology, Naval Postgraduate School.
- NAVSLaM is critical to EM predictions because it characterizes the important evaporation duct.
- Based on Monin-Obukhov Similarity Theory and the TOGA-COARE surface-layer parameterizations. Currently testing new stable Ψ profile functions.
- Inputs: wind speed, air and sea temperatures, relative humidity and pressure data obtained from NWP model forecasts, climatology datasets or in situ observations.
- Output: Near-surface vertical modified refractivity profiles for input to propagation models.

How NAVSLaM Fits Into the Radar Performance Prediction Process



Blending Upper-Air & Surface-Layer Refractivity Profiles

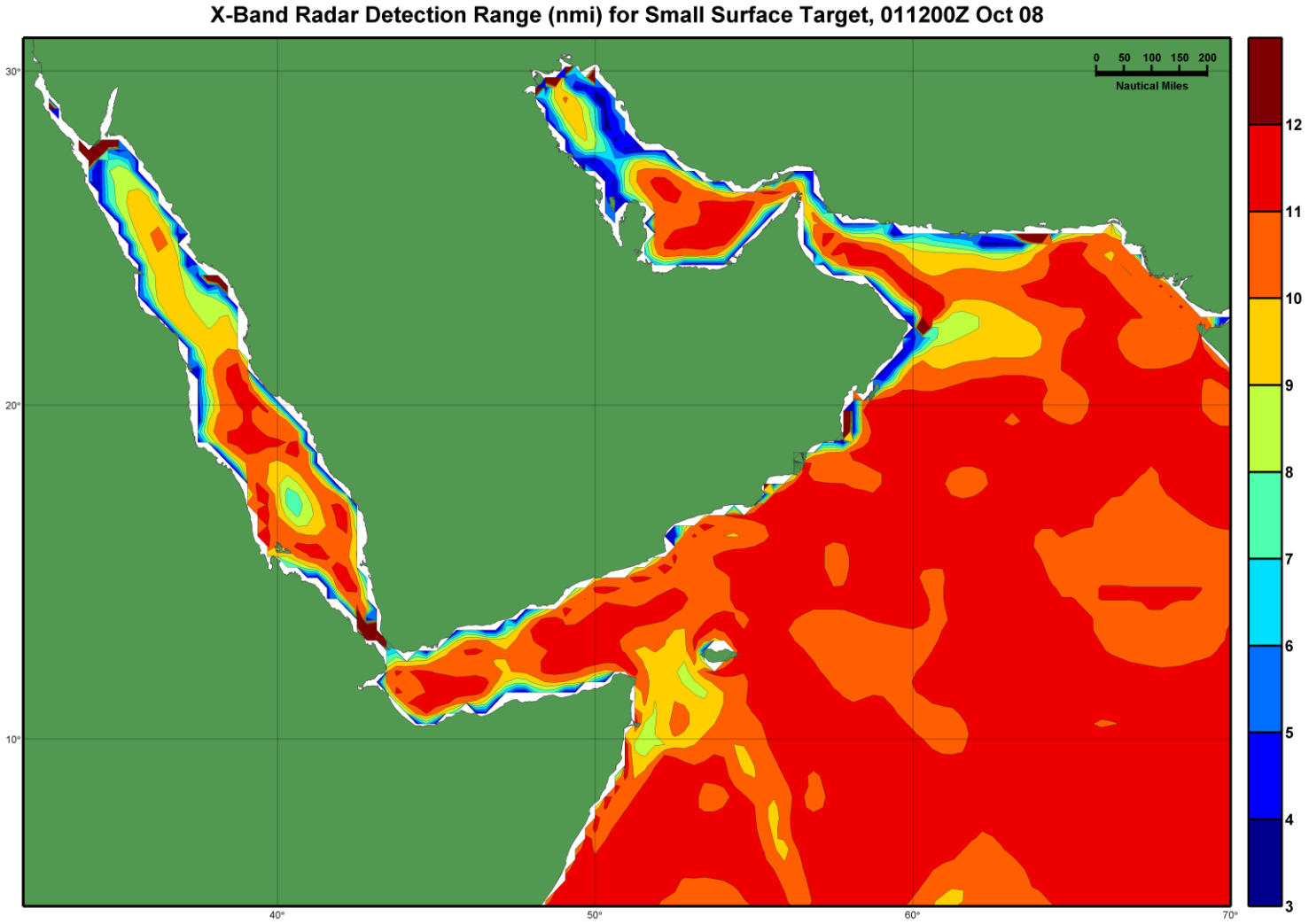
- The NAVSLaM surface-layer refractivity profile must be realistically blended onto the bottom of the COAMPS® or climatology upper-air profiles for accurate EM propagation predictions in all situations.



Example propagation loss coverage diagrams are for a 6 GHz radar at a typical shipboard height above the surface.

Radar Detection Range Modeling

- Radar detection ranges computed by APM/NAVSLaM using the new NPS evaporation duct climatology database based on the CFSR reanalysis.



Advanced Climate Analysis and Forecasting

- **Goal:** **Improve the representation of the effects of Earth's climate system on DoD, national intelligence, humanitarian assistance, and other operations.**
- **Includes:** **High resolution data sets describing past, present, and future environmental conditions at hourly to decadal scales**
- **Uses:** **Modeling and simulating environmental effects on people and systems (e.g., sensors, platforms, weapons), for example:**
  - **Design of systems and operations**
  - **Testing and evaluation**
  - **War gaming**
- **Partners:** **DoD, national intelligence, humanitarian assistance, and other organizations**

Advanced Climate Analysis and Forecasting

Focus Issues

1. **Regions:** PACOM, CENTCOM, AFRICOM, NORTHCOM, EUCOM
2. **Warfare Areas:** aviation, surface ship, USW, ground ops, spec ops, ISR
3. **Time Scales:** one week to years to decades ⇒ intraseasonal climate variations to multi-decadal climate change
4. **Atmosphere:** temperature, winds, clouds, storm tracks, tropical cyclones, thunderstorms, precipitation, lightning, electromagnetic ducting and radar performance
5. **Ocean:** currents, waves, temperature, salinity, sound speed, acoustic ducting and sonar performance, sea ice
6. **Land:** river flow, floods, droughts, dust storms,
7. **Regional and Operational Impacts of Global Climate Change:**
    a. Climate change and international security
    b. Climate change and water, food, and energy resources
    c. Impacts of climate change on combat and non-combat operations

Advanced Climate Analysis and Forecasting

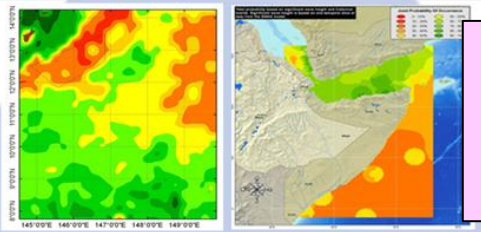
Tiers

Decision

Advanced long-lead decision support (e.g., analyses of options; risk and exploitation assessments; recommended COAs)

3

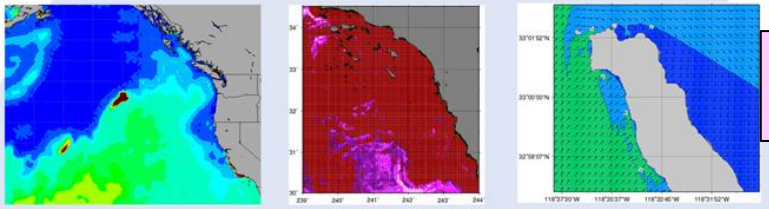
Performance



Advanced long-lead performance predictions (e.g., radar, sonar, adversary activity forecasts)

2

Environment



Advanced long-lead analyses and forecasts

1

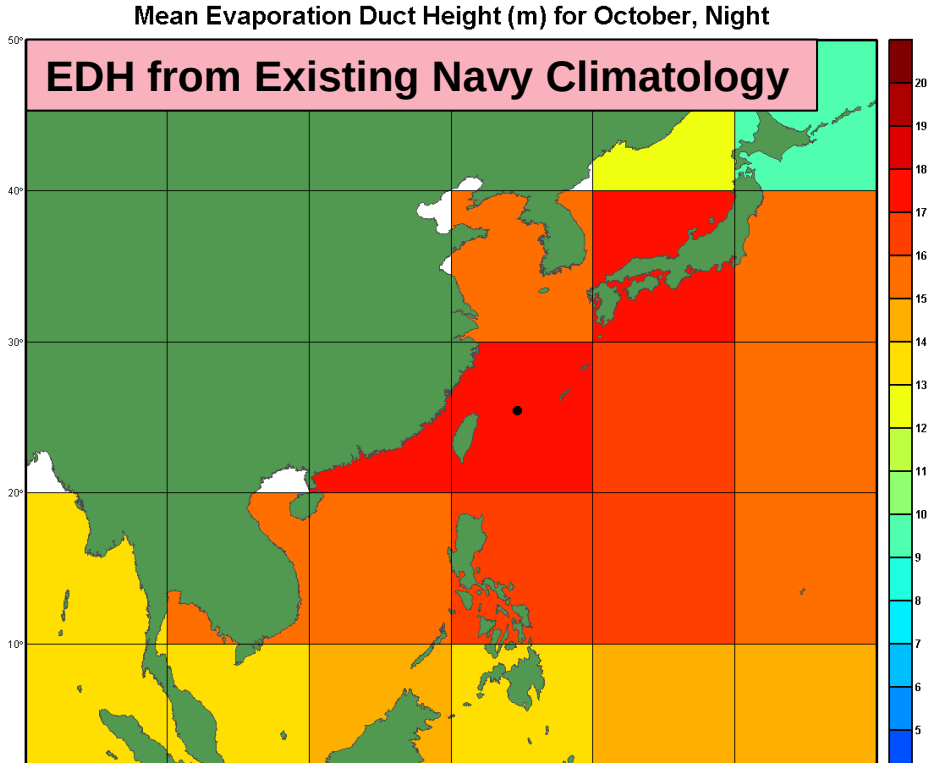
Data

Advanced long-term, high spatial and temporal resolution data sets

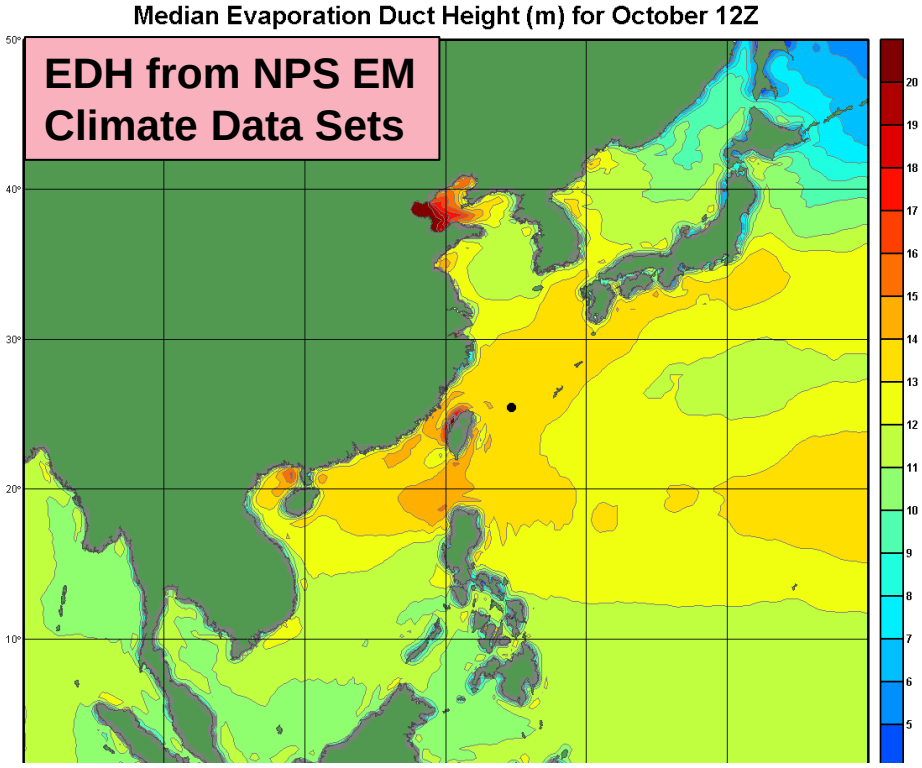
0

NPS climate analysis and forecasting program addresses all four tiers.

Improved Long-Term Data Sets



Evaporation duct height (EDH, m) from Navy's Historical Electromagnetic Propagation Conditions (HEPC) data set

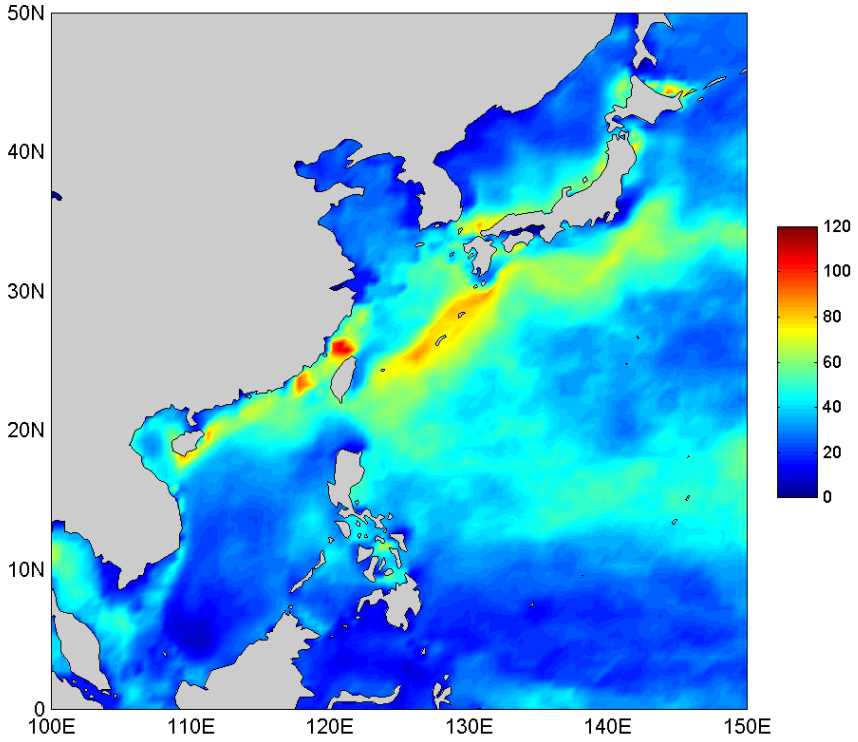


Evaporation duct height (EDH, m) from NPS EM climate data set, based on CFSR reanalysis data set

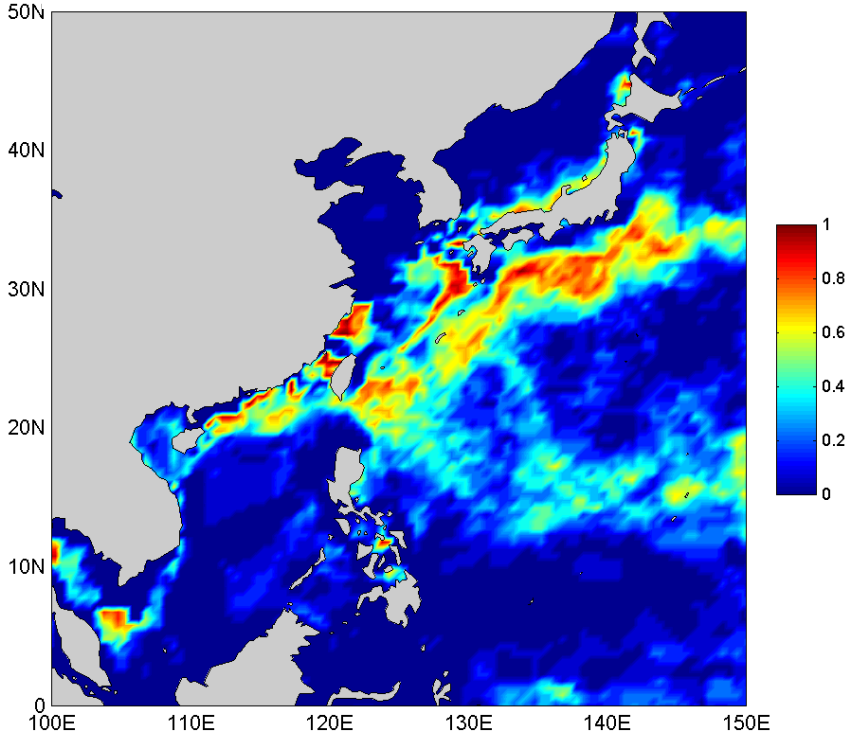
The modeling and simulation of environmental effects on operational planning, operations, and outcomes can be significantly improved through the development and application of *advanced* data sets.

Improved Long-Lead Forecasts

Sonic Layer Depth (SLD)



Probability of SLD = 50-70 m



The modeling and simulation of operational risks, risk management, and planning can be substantially improved via the use of advanced environmental data sets and forecasting methods that realistically account for environmental variability and uncertainty.

Results from NPS thesis research by S. Follett, (née Heidt), LCDR, USN, 2009

Improved Long-Lead Decision Support

Ocean Surface Winds and Waves Forecast for C3F

Month	Probability of Encountering at Least One Day With Conditions Above Thresholds in Any Set of 10 Days	Probability of Conditions Exceeding Thresholds
March	55%	Very High
April	35%	High
May	25%	Medium High
June	15%	Medium
July	10%	Medium
August	5%	Low
September	10%	Medium

M&S of environmental effects needs to realistically account for the effects of environmental variability and uncertainty on operational risk management.

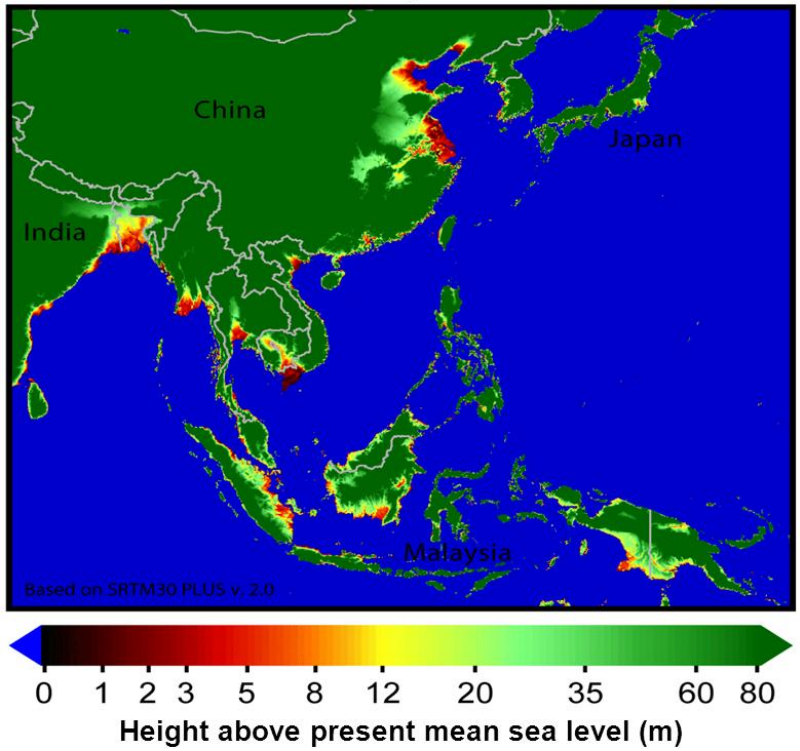
*** For more information, see notes section of this slide.**

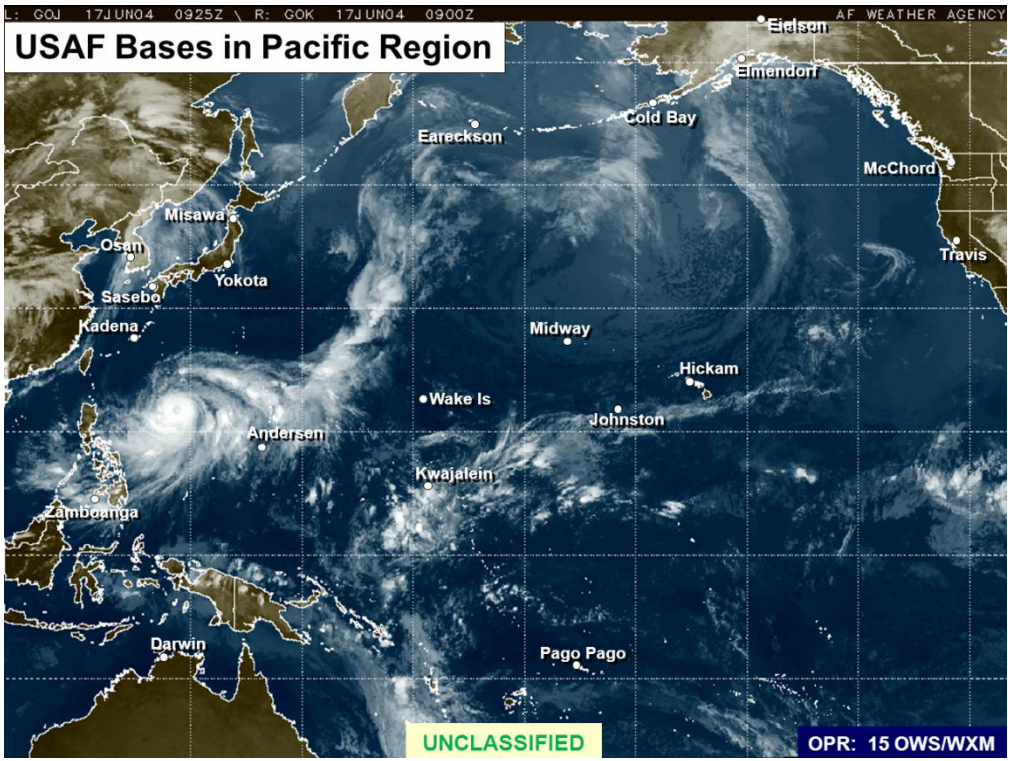
Global Climate Change:
Impacts on DoD Operations / QDR

1. Societal Impacts
2. Facilities / Infrastructure Impacts
3. Weapons Systems / Sensors / Warfighter Impacts
4. Operational Tempo Impacts

DoD required to address impacts of climate change on operations. Methods for doing so include M&S, gaming.

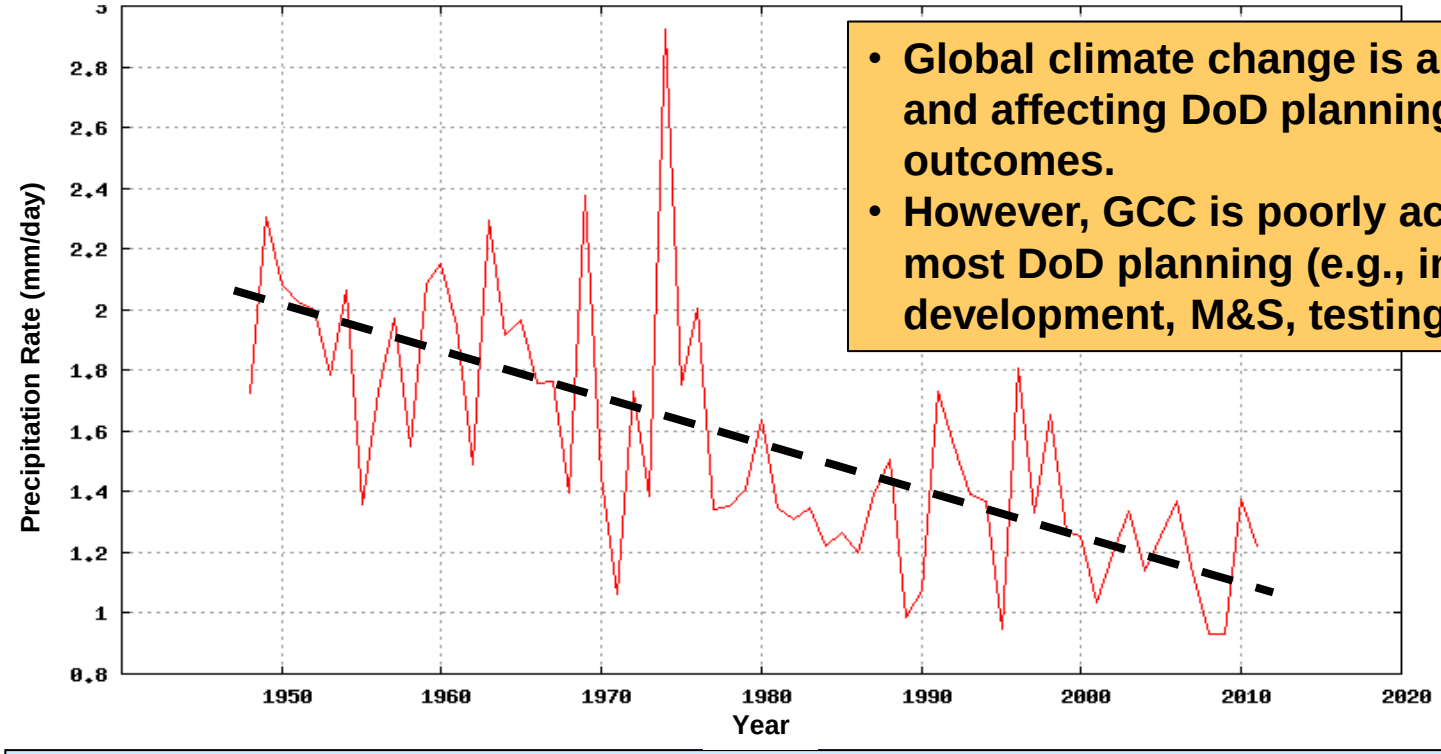
Risk of Coastal Flooding Due to Sea Level Rise





From: Murphree & Meyer (2009): Impacts of Global Climate Change on US Air Force Operations (report prepared for development of USAF components of 2010 QDR)

Global Climate Change Impacts: Iraq Precipitation, Jan-Mar, 1948-2010



- **Global climate change is already occurring and affecting DoD planning, operations, and outcomes.**
- **However, GCC is poorly accounted for in most DoD planning (e.g., in design, development, M&S, testing and evaluation).**

- **Winter is major season for precipitation in Iraq.**
- **Long term decrease in precipitation is one aspect of global climate change.**
- **Decrease has major implications for supply, demand, and development of water and hydroelectric energy resources, economic and political stability, and DoD ops.**
- **Other parts of CENTCOM AOR also show pronounced long term trends in precipitation, surface temperature, and other environmental variables.**

From Murphree and Meyer (2009)

NPS
Environmental Effects Group (EEG)

Contact Information:

- **Paul Frederickson, NPS Dept. of Meteorology: pafreder@nps.edu**
- **Peter Guest , NPS Dept. of Meteorology: pguest@nps.edu**
- **Arlene Guest , NPS Dept. of Oceanography: aguest@nps.edu**
- **Tom Murphree , NPS Dept. of Meteorology: murphree@nps.edu**

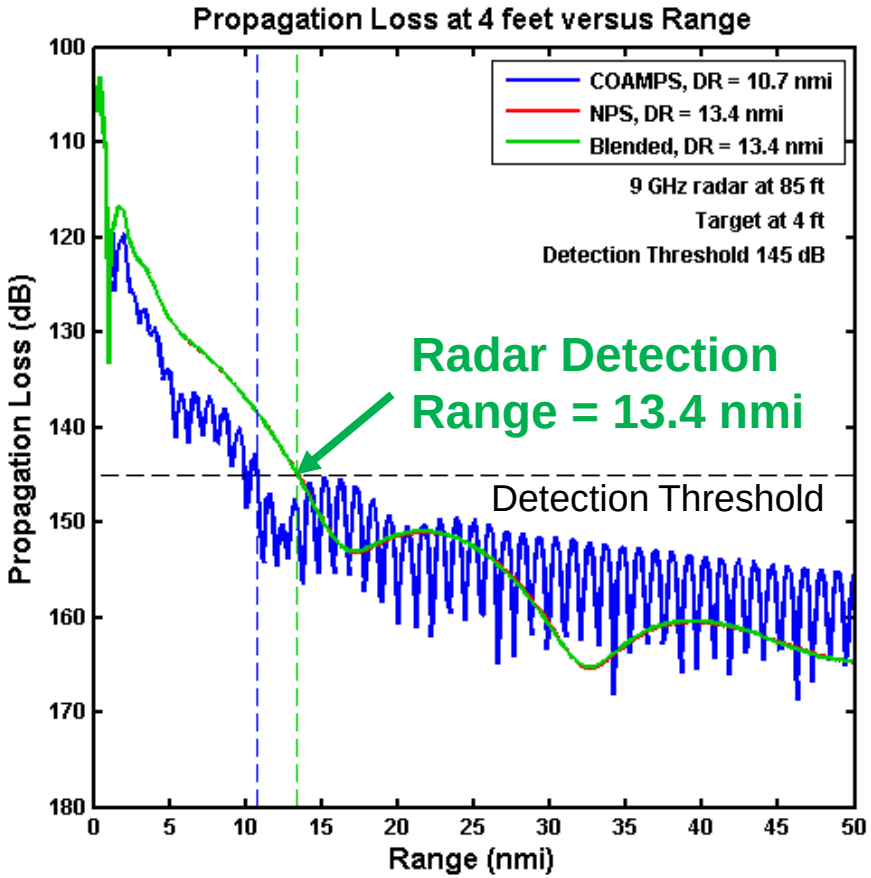
Backup Slides

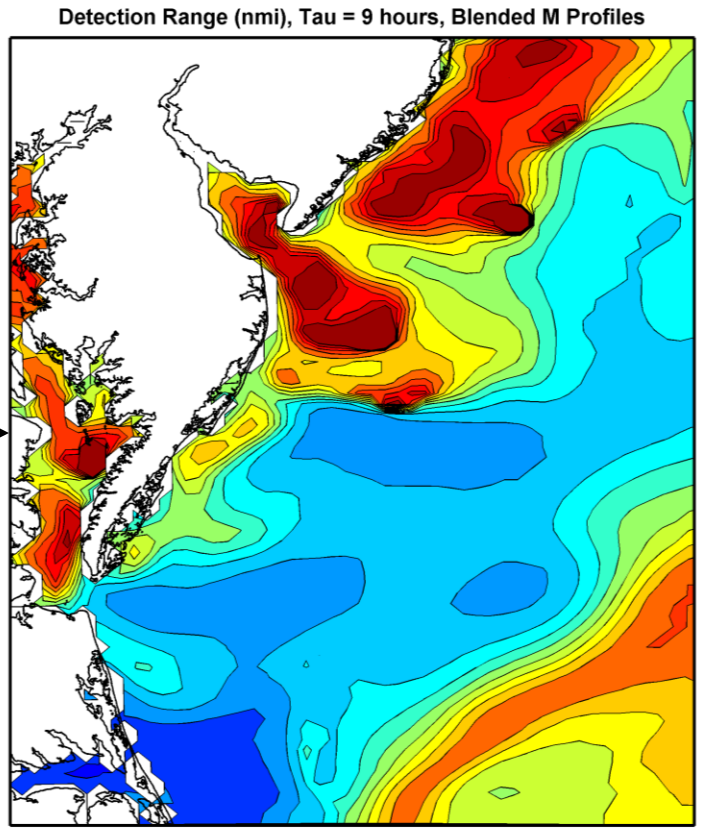
Results of Using NPS Blending Algorithm

Results are presented as "Atmospheric Performance Surfaces" which show a color-contoured map view of radar detection ranges for a specific radar & target scenario.

Compute radar detection ranges separately for each model grid point

Plot gridded detection ranges as a color-contoured map view, i.e. an "Atmospheric Performance Surface"



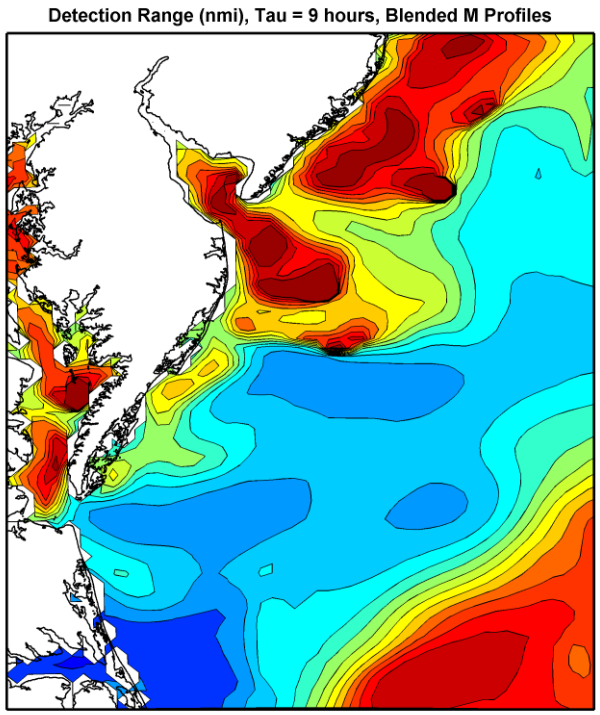


Wallops Is. 2000 COAMPS data courtesy of Tracy Haack, NRL-MRY.

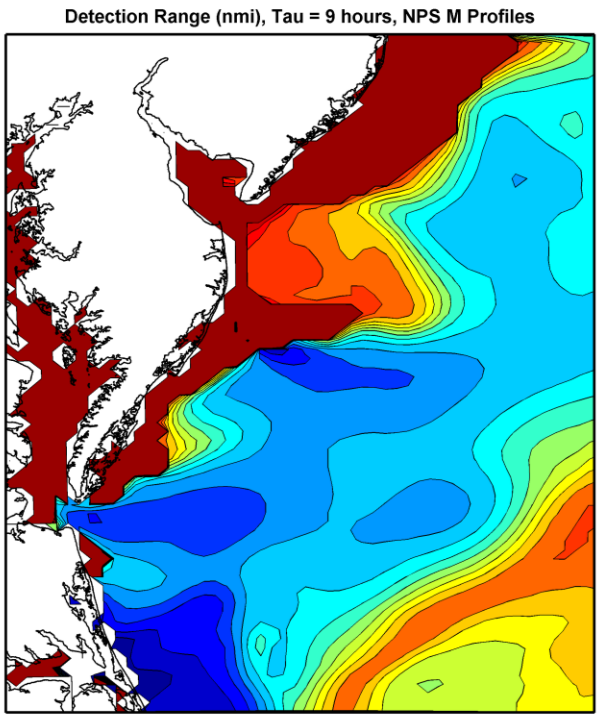
Atmospheric Performance Surfaces

Comparison of Atmospheric Performance Surfaces Using Different Near-Surface Refractivity Profiles

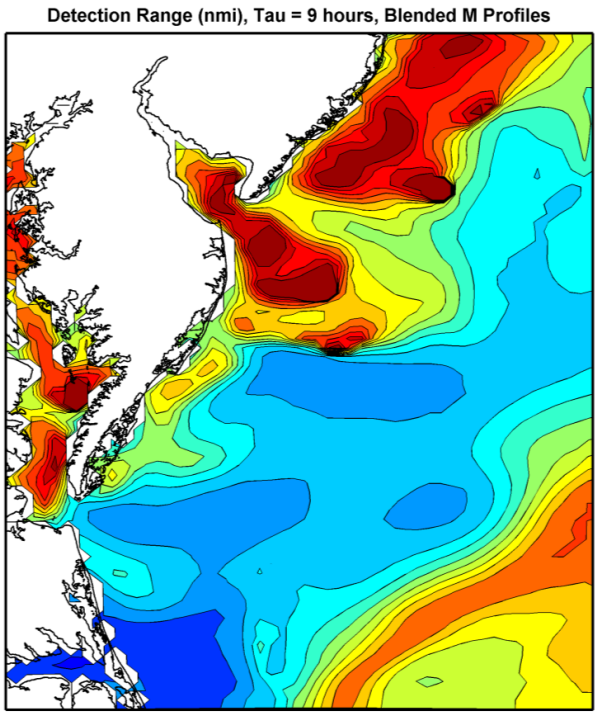
COAMPS with an Appended Profile below 5 m



NPS Profiles Only



Blended NPS & COAMPS Profiles



Wallops Is. 2000 COAMPS data courtesy of Tracy Haack, NRL-MRY.

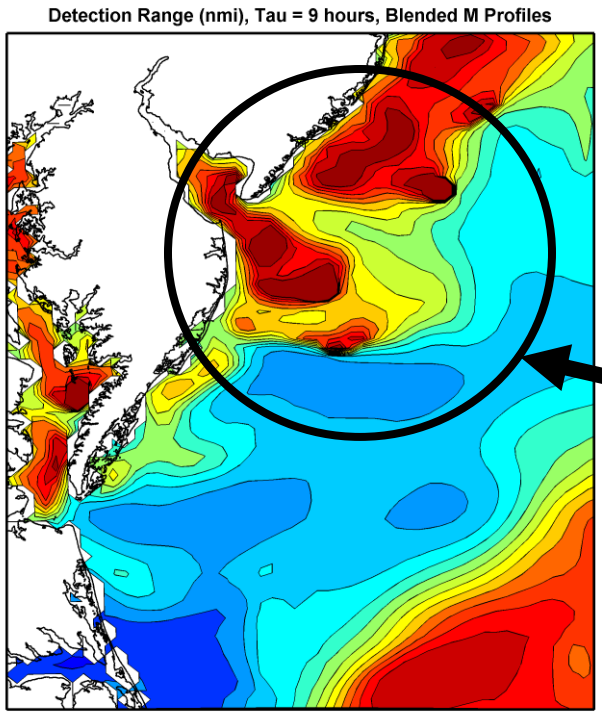
Atmospheric Performance Surfaces

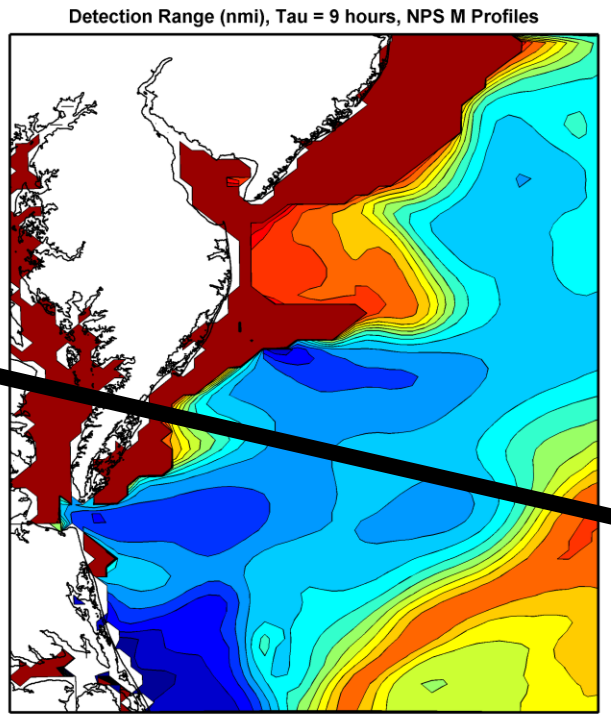
Comparison of Atmospheric Performance Surfaces (showing 90% PoD) Using Different Refractivity Profiles

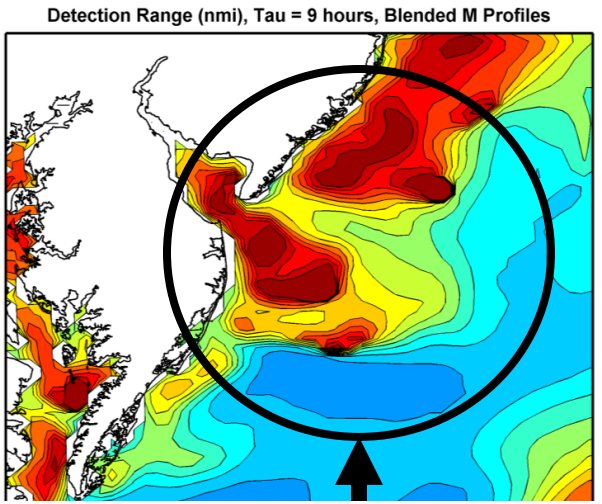
COAMPS with an Appended Profile below 5 m

NPS Profiles Only

Blended NPS & COAMPS Profiles







COAMPS with Appended Profile preserved in Blended ATPS in stable conditions

Wallops Is. 2000 COAMPS data courtesy of Tracy Haack, NRL-MRY.

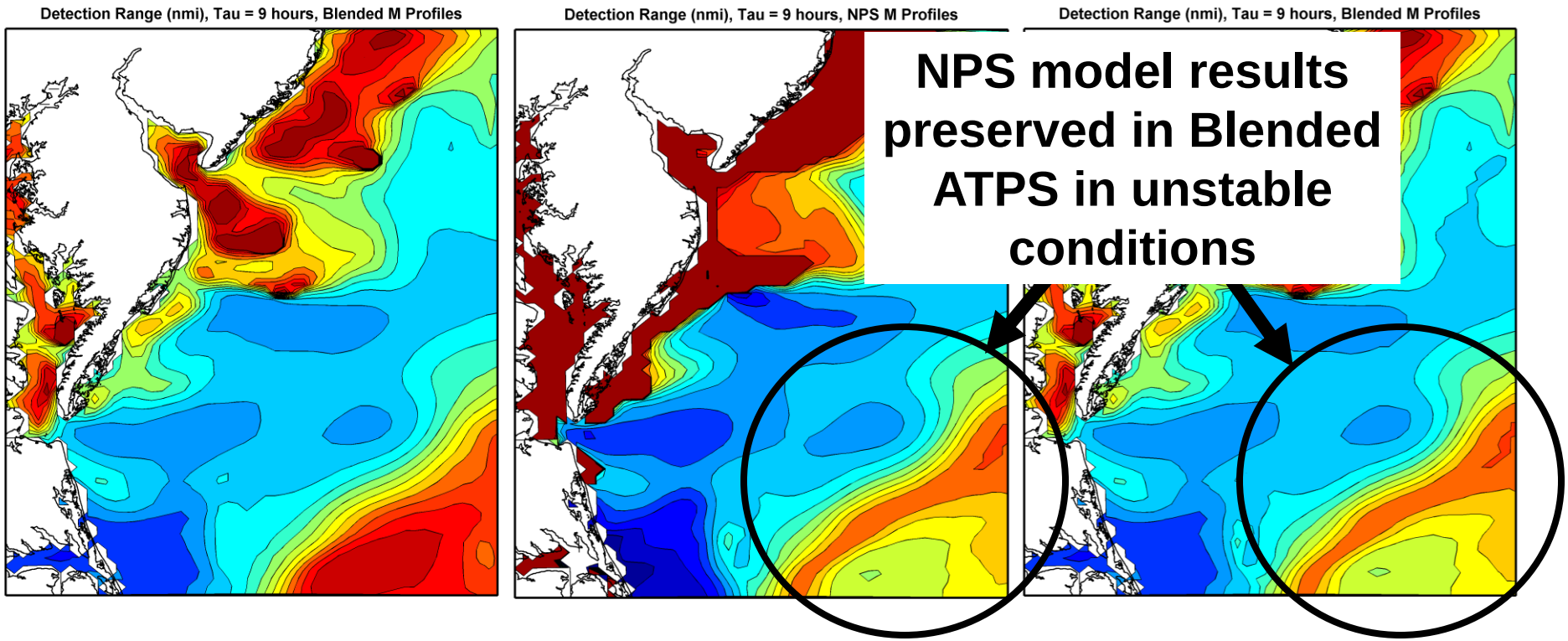
Atmospheric Performance Surfaces

Comparison of Atmospheric Performance Surfaces (showing 90% PoD) Using Different Refractivity Profiles

COAMPS with an Appended Profile below 5 m

NPS Profiles Only

Blended NPS & COAMPS Profiles



Wallops Is. 2000 COAMPS data courtesy of Tracy Haack, NRL-MRY.

Movie Loop of Evaporation Duct Height

This movie loop shows the progress of EDH in the Western North Pacific for each hour of 1 July 2008.

Note that the high spatial and hourly temporal resolution is very valuable to distinguish diurnal variations in EDH, particularly in coastal regions.

Note especially the variations in EDH in the Taiwan Strait, East China Sea and Yellow Sea.

(To play the movie, please click on the figure while in slideshow mode.)